

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

(12) DEMANDE INTERNATIONALE PUBLIÉE EN VERTU DU TRAITÉ DE COOPÉRATION  
EN MATIÈRE DE BREVETS (PCT)

(19) Organisation Mondiale de la Propriété  
Intellectuelle  
Bureau international



(43) Date de la publication internationale  
11 avril 2002 (11.04.2002)

PCT

(10) Numéro de publication internationale  
**WO 02/29208 A1**

(51) Classification internationale des brevets<sup>7</sup> :

**E21B 43/10, 41/00**

(81) États désignés (*national*) : CA, GB, US.

(21) Numéro de la demande internationale :

PCT/FR01/03099

Déclaration en vertu de la règle 4.17 :

— relative à la qualité d'inventeur (règle 4.17.iv)) pour US  
seulement

(22) Date de dépôt international : 8 octobre 2001 (08.10.2001)

Publiée :

— avec rapport de recherche internationale

(25) Langue de dépôt :

français

(26) Langue de publication :

français

En ce qui concerne les codes à deux lettres et autres abréviations, se référer aux "Notes explicatives relatives aux codes et abréviations" figurant au début de chaque numéro ordinaire de la Gazette du PCT.

(30) Données relatives à la priorité :

60/239,011

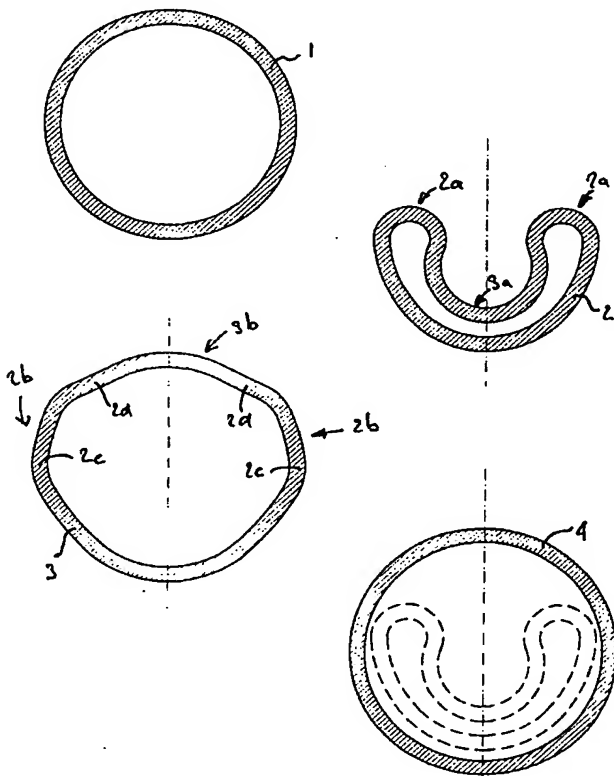
6 octobre 2000 (06.10.2000) US

(71) Déposant et

(72) Inventeur : NOBILEAU, Philippe [FR/FR]; 2, avenue  
Fernand Martin, F-06230 Villefranche sur Mer (FR).

(54) Title: METHOD AND SYSTEM FOR INCREASING TUBING RESISTANCE TO PRESSURE

(54) Titre : METHODE ET SYSTEME POUR AUGMENTER LA RESISTANCE A LA PRESSION D'UN CUVELAGE



(57) Abstract: The invention concerns a method for enhancing resistance to external pressure in a tube installed in a previously lined borehole, providing a passage through its tube of reduced dimension. Said method is characterised in that it consists in lowering the tube in a first shape (2) whereof the dimensions are smaller than the reduced section, shaping it to enable it to shift from said first form to a second substantially cylindrical shape (3) having a dimension larger than the reduced section and expanding it by moving a cylindrical expanding mandrel through the tube whereof the expansion value ranges between 2 and 10 % of the value of the external diameters.

(57) Abrégé : Méthode permettant d'améliorer la résistance en pression extérieure d'un tube mis en place dans un puits préalablement cuvelé, qui offre un passage à travers son cuvelage de dimension réduite, la méthode étant caractérisée en ce qu'elle comprend la descente du tube sous une première forme (2) dont les dimensions sont inférieures à la section réduite, la mise en forme pour le faire passer de ladite première forme à une deuxième forme (3) sensiblement cylindrique ayant une dimension supérieure à la section réduite et l'expansion par déplacement d'un mandrin dilateur cylindrique à travers le tube dont la valeur d'expansion est comprise entre 2 et 10 % de la valeur des diamètres extérieurs.

WO 02/29208 A1

## METHOD AND SYSTEM FOR INCREASING PIPE RESISTANCE TO EXTERNAL PRESSURE

### Technical Field:

5 This invention relates to installing well casing in oil wells and in particular, a method and system to improve resistance in external pressure external of a pipe run into a well through a preceding casing with reduced diameter requiring a plastic deformation then gaining its final dimensions in a cavity located below the reduced diameter of the preceding casing.

### Background Art :

10 Oil and gas wells are typically drilled by installing a conductor pipe to first depth, then drilling the well to a second depth. Usually, a string of casing is made up by coupling together sections of pipe, each being about forty feet long, and lowering the string through the conductor pipe to the second depth. Cement is then pumped down the casing, which flows back up the annulus between the casing and the open borehole. Drilling is resumed to a third  
15 depth and the process is repeated with another smaller diameter nested casing. An even smaller diameter string of casing may be installed to a fourth depth.

Casing serves to support the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole from strata other than the target production strata. The nested arrangement of successively smaller casing  
20 strings requires a relatively large borehole at the upper part of the wellbore due to the thickness of the casing and couplings and also due to the minimum clearance necessary between casing to displace cement in the annulus space.

US Patent 5,794,702 discloses a continuous collapsed casing system allowing to rapidly run a continuous metallic casing into a well. The casing is plastically coiled on large reels. An  
25 injector unit straightens the casing and folds it in horseshoe shape prior to lowering it into the well as it is uncoiled from the reel. When the casing has attained the depth required, it is then reopened mechanically or hydraulically.

The US patents 5,979,560 and 6,253,852 of the inventor describe downhole well equipment comprising lowering of sections of pipe which are folded longitudinally to allow  
30 their descent in the well, then re-inflated by internal pressure to regain their initial cylindrical shape.

Through a casing, a casing of smaller diameter having a cylindrical form can be lowered and its diameter increased by stretching the wall of the pipe using an expansion mandrel. In

this case an expansion mandrel is pushed or drawn including a first diameter equal to the internal diameter from the pipe and a second diameter equal to the internal diameter that is desired to obtain, these two diameters being connected by a truncated cone. It is on this truncated cone that the plastic dilation of the wall of the pipe occurs which must be at least of the order of 15% in external diameter increase, and it is the axial length of this cone which limits the thickness of the pipe considered due to the risk of causing cracks by striction initiated on micro defects in the zone which is highly stretched plastically.

These various methods thus allow the installation of pipe of a given diameter given through a preceding pipe of reduced diameter requiring a plastic deformation to take its final dimensions in a cavity located below a preceding casing of reduced diameter and being deformed plastically, in one step, to obtain its final diameter.

But this operation results either in an irregular section of the pipe, which keeps the fold marks made during folding, in the case the section was initially folded, or in a thickness limitation, in the case where the pipe is initially cylindrical and is simply expanded. Due to these irregularities or reduced thickness, the external pressure resistance is largely decreased compared to the equivalent casing installed in a traditional way, the next smaller through the larger precedent ones.

#### **Disclosure of Invention:**

Consequently, the aim of the invention is to offer a method to improve the external pressure resistance of the pipe which must be deformed plastically to take the final shape and dimensions, independently of the technique used to get them through the well. This method improves the external pressure resistance of the pipe by improving either the circularity of the section in case it has been folded or by allowing the use of heavier pipes in the case it has been only expanded.

The aim of the invention is thus a method allowing to enhance the external pressure resistance of a cylindrical pipe installed in a cased well, offering a reduced opening through its casing, the method comprising the descent of the pipe in an initial shape whose dimensions are smaller than the reduced opening, the deformation to convert it from the first shape in a second shape substantially cylindrical having a dimension larger than the reduced opening and characterized by the expansion of the cylindrical pipe to the second form by displacement of an expansion mandrel through itself, the peripheral expansion lying between 2 and 10 % of the value of the initial perimeter.

This method applies to the system of casing in monodiameter which consists in lowering a string of casing into a well through a preceding casing of common diameter, and to enlarge this casing by unfolding or expansion to the common diameter.

More generally, this method applies to any section of pipe which must temporarily pass through an opening of smaller size at the time of its running into a well and must take again by plastic deformation a final diameter larger than the dimensions of the opening by which it has momentarily to pass through.

In a characterization of the invention, the expansion mandrel will be moved by applying a pressure behind, sealing of the mandrel in the casing being located in front of the wedging shape of the expansion mandrel.

**Short description of the drawings:**

Figure 1 is a sectional view of the initial pipe as being manufactured.

Figure 2 is a sectional view of the pipe folded up as it is lowered into the well.

Figure 3 is a sectional view of the pipe re-inflated by the pressure of the opening fluid.

Figure 4 is a sectional view of the slightly expanded final pipe giving a passage sufficient for the passage of the next pipe according to figure 2.

Figure 5 is a perspective view for the expansion mandrel of the first embodiment of the invention.

Figure 6 is a partial sectional perspective view of the passage of the expansion mandrel for the first embodiment of the invention.

Figure 7 is a perspective view of a folded up apparatus passing through a casing of reduced diameter.

Figure 8 is a partial sectional perspective view of the apparatus of figure 6 re-inflated.

Figure 9 is a perspective view of the double step expansion mandrel.

Figure 10 is a partial sectional perspective view of the passage of the double step expansion mandrel of figure 9.

Figure 11 is a partial sectional perspective view of a folded up casing as it is lowered.

Figure 12 is a partial sectional perspective view of an expansible casing as it is lowered.

Figure 13 is a partial sectional perspective view of the final casing with the head of casing swaged into the foot of the preceding casing and with the shoe drilled out.

**Best mode for carrying the invention :**

On figure 1, the section of pipe 1 as manufactured is circular and regular. Before being transported to the drilling site, this pipe is folded up in a U-shape 2 as illustrated on figure 2 to

reduce its radial dimensions and to allow its passage in the preceding casing made up of same diameter casings. The casing which can have a length of a few hundred meters to thousands of meters is either continuous and rolled up on a reel in the folded up configuration, or assembled at the surface at the vertical of the well from 12 meters length of casing, folded up  
5 on almost the entire length with the exception of the ends.

Irrespective of the assembly or transportation to the drilling site, the casing is lowered into the well then re-inflated by pumping fluid into the casing. The re-inflation with pressure gives a section 3 illustrated by figure 3. As we can see this section is somewhat circular but irregular and presents the mark of the folds made during the folding of the section. Indeed, the  
10 convex folds 2a are found in 2b and the concave fold 3a is found in 3b. In fact, it is not the folds that stay but the ends of folds which become hard point.

If these irregularities have little effect on the interior pressure capacity of the casing, the localized existence of large radius of curvature 2c and flat part 2d affects the performances in external pressure considerably when compared to the external pressure performances of the  
15 initial casing.

On figure 5, the expansion mandrel 100 comprises an active part 101 materialized by a cylinder with the expansion diameter preceded by a expansion cone 102. At the top, it is connected to the bottom of the drill string 107. The expansion mandrel can thus fulfill its duty using the weight of the drillstring, increased by drill collars (not represented) to carry out the  
20 expansion phase. At last a guide conical head 104 is located at the bottom.

In some case, for instance when the drilling is horizontal or almost horizontal, or when applying sufficient weight on the expansion mandrel is not practical, it could be advantageous to pump the expansion mandrel and in this case one or several high pressure cups 103 of elastomeric material pressure are inserted on the expansion mandrel body usually on top of  
25 this one in order to apply a thrust on it by establishing a sliding seal with the internal surface, rough of rolling, of the casing.

Nevertheless it can be advantageous to locate the cups 103 ahead of the expansion mandrel as illustrated on figure 5 so first to propel the expansion mandrel and second to use the thrust pressure to apply internal pressure on the part of pipe to be expanded. Indeed this lowers the  
30 axial thrust required by putting the casing in hoop tension and decreasing the contact forces between the casing and the cylindrical part 101 of the expansion mandrel.

On figure 6, the expansion mandrel 103 is forced through casing 99 to carry out a slight expansion of the circumference of the pipe in the plastic range. The section 105 which has the

shape of figure 3 is stretched while passing on cone 102 followed by the cylindrical part 101 and takes the shape 106 of figure 4. This slight expansion allows to reduce substantially the mark of the folds and in fact impose the smooth shape to the casing which takes back the shape illustrated on figure 4. This expansion increases the length of the external circumference of the casing by 2 to 10% (figure 1 and 4) and thus in consequence the external diameter with the same ratio.

Referring to figure 11, casing 6 of folded up casings is made of multiple lengths of folded up casings 8. Casing 6 comprises a top hanger 26 on top connected with lengths of casing 8 to an also folded up bottom bell 28 and a partially folded up shoe 34. The top hanger 26 comprises collet fingers 30. Hanger 26 also comprises circumferential triangular grooves 27 on its external surface. Preferably, a soft metal inlay is located in triangular bottom of groove 27 to enhance sealing. A profile with interior groove 31 is located on the internal diameter of top hanger 26 to permit connection with the running tool 50 (not shown). Casing 8 connected to the hanger 26 can extend in casing string 6 on thousands of meters.

The bottom bell 28 comprises a profile with interior groove 32 to receive the collet fingers 30 of the next top hanger 26 of the casing (not shown) which will be suspended below. The bottom bell 28 has a surface of triangular groove 29 which of similar manner cooperates with the triangular grooves 27 of the top hanger 26 of the next casing (not shown) which will be suspended below.

The cementing shoe 34 is offset from the casing 6 axis and comprises a check valve 35 with an upper sealing seat 38, a lower sealing seat 36 maintained in place by shearing pins 37, sealed in the cementing shoe 34 by seals, a floating ball 39 and one passage of fluid 40 connecting the check valve 35 to the bottom nozzle. Figure 11 shows casing 6 and the top hanger 26 in a running configuration. The top hanger 26 and shoe 34 are not folded up. The top hanger 26 will be initially expanded to allow the descent of the running tool and expansion mandrel (not shown), then will be finally swedged to the bottom bell 28 of the preceding installed casing.

The figure 12 shows the same configuration of casing as figure 11 with the exception that the body of the casing consists of expandable pipes 8' and not folded up 8 but we find the same expandable top hanger 26 and folded up bottom bell 28 described on figure 11.

Referring on figure 13, the top hanger 26 is suspended on preceding unfolded casing 5 by the collet fingers 30. The triangular grooves 27 were deformed to interpenetrate the triangular grooves 28 of preceding casing 5. Casing 8 was rounded.

As can be seen, a monodiameter casing system can be built around a folded up casing. The reduction of diameter for its descent through preceding casing of the same dimension can be obtained from the technique of pipe folding or the known technique of brutal pipe expansion. As we have just seen, it is advantageous to combine the techniques of folding and expanding  
5 by folding up a casing of 6-5/8" to obtain a diameter external of 6" and then in the place of expansion mandrel to the same diameter to dilate it slightly to obtain a diameter of 7" (5,7% of expansion) and in consequence being able to combine the capacity of thick pipes and the limited strain of the folded up technique with the good geometry of the expanded technique. If we wanted to take a casing of 6" which passes through a casing of 7", and to expand it to  
10 obtain a casing of 7", it is an expansion of 16,7% that would be required with the limitations which were mentioned previously. We can obtain a similar result by associating a first expansion with a second one and to thus limit the value of expansion which must be carried out at once.

Despite the fact that the casings are considered as assemblies from straight lengths in the  
15 above description, continuous casings on reels as described in the US patent 5,794,702 can be also used to build a system of casing "folded/re-inflated" benefiting of the external pressure enhancement from the inflation followed by a slight expansion described above.

In a second embodiment of the invention, a downhole equipment 110 (figure 7) comprising sections of pipe 111a and 111b is crushed with its sections of pipe folded up to allow its  
20 descent in the reduced passage of well casing 115. An example of such equipment is described in the US patents 5,979,560 and 6,253,852.

When this equipment reaches the target depth which features a widened cavity (not shown), the equipment is re-inflated (figure 8) by pumping fluid which will give it a general cylindrical shape 120. But as previously said, this re-inflated shape exhibits on the straight  
25 parts of the pipes 111b and 112b of the equipment, some variations of radius localized at the previous fold location (see figure 3) and it is necessary to eliminate them to improve the external pressure resistance of these sections. This is carried out by a mechanical action of slight expansion mandrel (figure 5) such as previously described for the first embodiment which is run on drillpipe through the equipment and which enters successively the two  
30 branches 111b and 112b to carry out a slight expansion of the pipes constituting those branches.

In the case of downhole equipment 110, which comprises two branches 111 and 112, it is advantageous to fold them with a fold on each pipe 116 and 117 facing one another which



gives sections 121 and 122 a U-shape face to face. The marks of the folds 116 and 117, which persists after re-inflation (figure 3) are completely erased by the slight expansion and the sections become again perfectly circular 123 and 124 with an increase in diameter from 2 to 10 %.

5 On figure 9, the expansion mandrel 200 comprises an active part 201 made up by two expansion cylinders, one having the final expansion diameter 211 and the other roughly with the intermediate diameter 212 between the final diameter and the diameter of the initial expandable casing. These diameters are preceded by two expansion cones 213 and 214 respectively. The top part is secured on the drillstring 107. The expansion mandrel can thus  
10 fulfil its duty by using the weight of the drillstring, weighed down by drillcollars (not shown) to perform the expansion task. At last a conical head 104 is located on the lower part.

In some case, for instance when the drilling is horizontal or almost horizontal, or when applying sufficient weight on the expansion mandrel is not practical, it could be advantageous to pump the expansion mandrel and in this case one or several high pressure cups 103 of  
15 elastomeric material pressure are inserted on the expansion mandrel body usually on top of this one in order to apply a thrust on it by establishing a sliding seal with the internal surface rough of rolling of the casing.

Nevertheless it can be advantageous to locate the cups 103 below the expansion mandrel as illustrated on figure 9 in order to use the pressure thrust to apply internal pressure to the part  
20 of pipe to be expanded (206, 208). Indeed this lowers the axial thrust required by putting the casing in hoop tension and decreasing the contact forces between the casing and the cylindrical part 211 and 212 of the expansion mandrel 200.

On figure 10, the expansion mandrel 200 is forced through the expandable casing 199 to carry out successively two distinct expansions of the circumference of the pipe in the plastic  
25 range. The initial section 205 which is circular is stretched in the shape of cone 206 while passing on cone 214 followed by cylinder 212 and obtains the round diameter 207 then is again stretched in the shape of cone 208 while passing on cone 213 followed by cylinder 211 and obtains the round diameter 209. This expansion in two stages 206 and 208 makes it possible to expand heavier wall thickness pipe while an expansion in only one stage would  
30 require a plastic zone of the double length which would increase the possibility of longitudinal failure from the stretched area due to a defect of a given size. It is well understood that the stretched zone must be maintained in the hoop direction to avoid the

formation of striction in presence of defects, while as soon as the expansion ratio is increased above 10%, the tolerance to defect is substantially decreased.

Despite the fact that the casing strings are made of coupled straight joints in the description, continuous casing on reel can also be used to obtain a monodiameter well casing system.

Consequently, the aim of the invention is to offer a method to improve the external pressure resistance of the pipe which must be deformed plastically to take the final shape and dimensions independently of the technique used to get them through the well. This method improves the external pressure resistance of the pipe by improving either the circularity of the section or by allowing the use of heavier pipes.

The aim of the invention is thus a method allowing to enhance the external pressure resistance of a cylindrical pipe installed in a cased well, offering a reduced opening through its casing, the method comprising the descent of the pipe in an initial shape whose dimensions are smaller than the reduced opening, the deformation to convert it from the first shape in a second shape substantially cylindrical having a dimension larger than the reduced opening and characterized by the expansion of the cylindrical pipe to the second form by the displacement of an expansion mandrel through the pipe, the peripheral expansion percentage lying between 2 and 10 % of value of the initial perimeter.

This method applies to the system of casing in single diameter which consists in lowering a string of casing into a well through a preceding casing of common diameter, and to enlarge this casing by unfolding or expansion to the common diameter.

### Claims

1. Method allowing to enhance the external pressure resistance of a cylindrical pipe (1, 111, 6, 99, 199) installed in a cased well (115, 5), offering a reduced opening through its casing, the said method comprising:

5 a) the descent of the said pipe in a first shape (2, 110) whose dimensions are smaller than the said reduced opening,

b) the deformation of said pipe to convert it from the said first shape in a second shape (3, 207) substantially cylindrical, having at least a dimension larger than the said reduced opening, and characterized by:

10 c) the expansion of the cylindrical pipe to the second form (4, 209) by displacement of an expansion mandrel (100, 200) through itself, the peripheral expansion lying between 2 and 10 % of value of the initial perimeter.

2. Method according to claim 1 in which the said first shape is obtained by folding (2) before step a) and the said deformation of step b) being done by unfolding (3).

3. Method according to claim 2 in which the said unfolding (3) is done by a gauge displacement.

20 4. Method according to claim 2 in which the said unfolding (3) is done by hydraulic re-inflation.

5. Method according to claim 1 in which the said first shape is cylindrical (199), the said deformation of step b) (207) is achieved by displacement of a first expansion mandrel (212) through the said pipe (199), and in step c) the expansion done by a second expansion mandrel (211) of larger diameter.

6. Method according to claim 1 in which the expanded pipe (209) after step c) has an external diameter equal to the external diameter of said casing it went through at step a) (115).

30 7. Method according to claim 1 in which an internal pressure is applied on the pipe on the part (206, 208) subjected to the expansion of step c) in order to minimize the thrust on the expansion mandrel.

8. Method according to claim 1 in which the expansion of step c) is done by an expansion mandrel (100, 200) pushed hydraulically by locating high pressure cups (103) on the said expansion mandrel in sealing arrangement with the internal surface of said pipe and applying  
5 a pressure, behind of said expansion mandrel with regard to its displacement direction, to propel it.

9. Method according to claim 7 and 8 in which the said high pressure cups are located in front of the expansion mandrel (100, 200) with regard to its displacement direction and the  
10 said pressure, applied to propel the said expansion mandrel, apply also on the said part (206, 208) subjected to the expansion of step c).

10 Method according to claim 5 in which the expansion of step c) is done by said expansion mandrel (200) placed on the same body as the expansion mandrel carrying out the  
15 passage of the aforementioned first form to the aforementioned second form.

11 Method according to claim 1 in which two pipes (111a and 111b) are side by side during step a) and these two pipes (121, 122) have a fold (116 and 117) each facing one another.

20 12 System allowing to enhance pipe external pressure resistance after having been folded then rounded wherein a limited hoop expansion is applied to remove the fold strain.

13 System allowing to enhance pipe external pressure resistance after having been partially expanded wherein a limited hoop expansion is applied to prevent localization of strain.  
25

30  
Abrégé :

**Abstract:**

5       The invention concerns a method for enhancing resistance to external pressure to a pipe  
installed in a previously cased borehole, which offers a passage through its opening of  
reduced size. Said method consists in lowering the pipe in a first shape (2) whereof the  
dimensions are smaller than the reduced opening, in deforming it to convert it from the first  
shape in a second shape substantially cylindrical (3) having a dimension larger than the  
10 reduced opening and characterized by the expansion of the cylindrical pipe of the second form  
by displacement of an expansion mandrel through the pipe, the peripheral expansion lying  
between 2 and 10 % of the value of the initial perimeter.

15

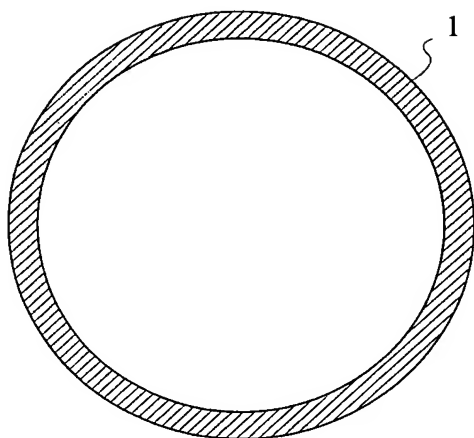


Fig 1

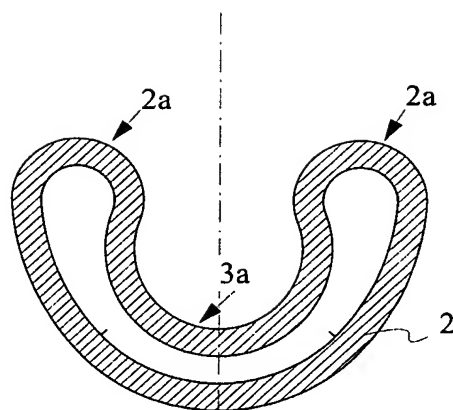


Fig 2

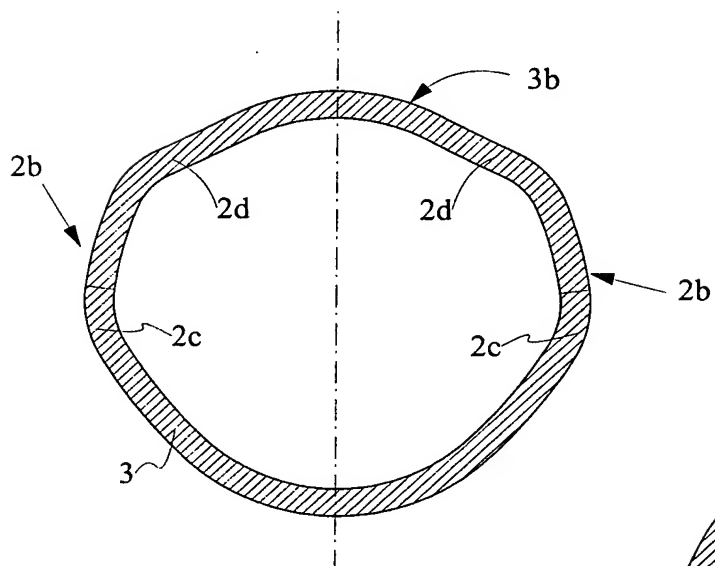


Fig 3

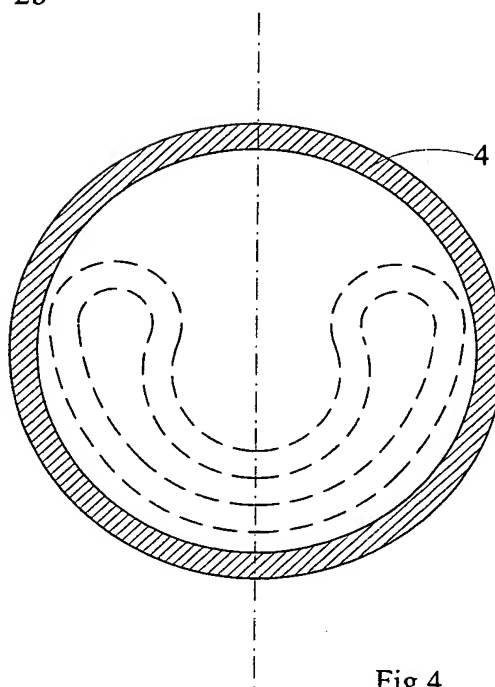


Fig 4

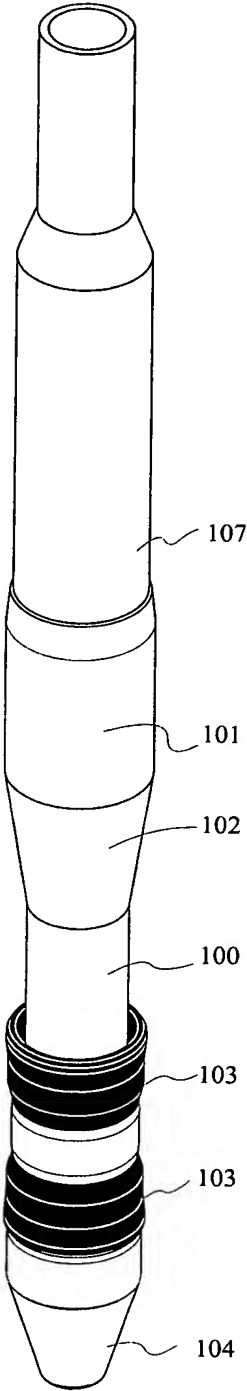


Fig 5

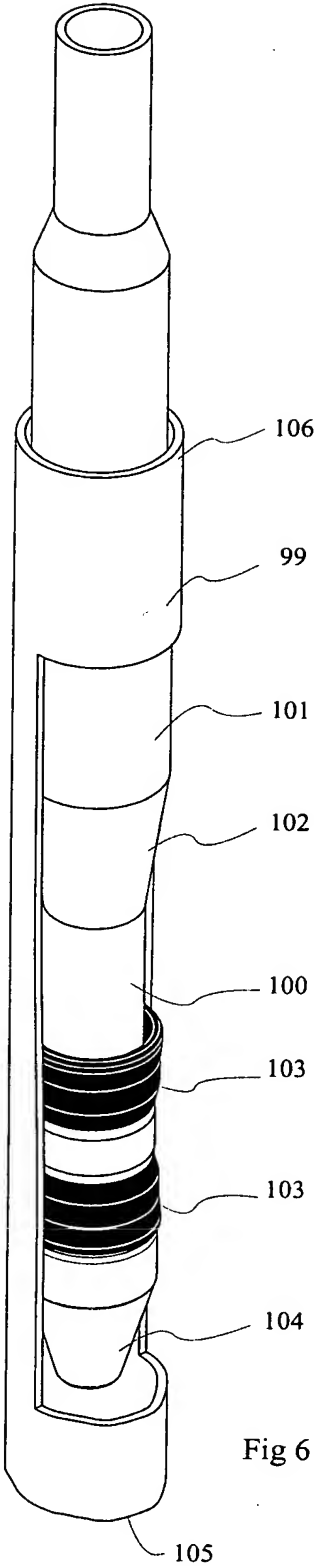


Fig 6

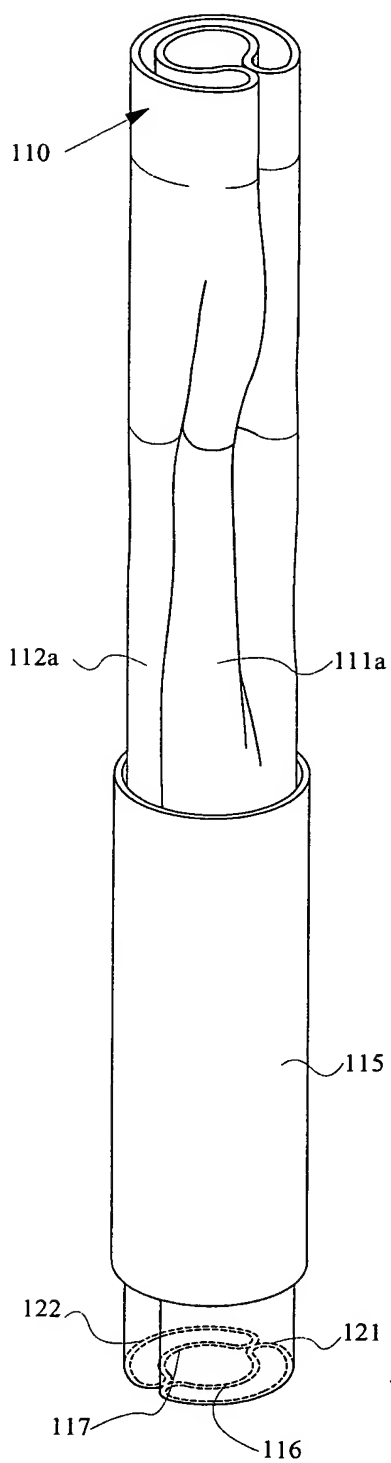


Fig 7

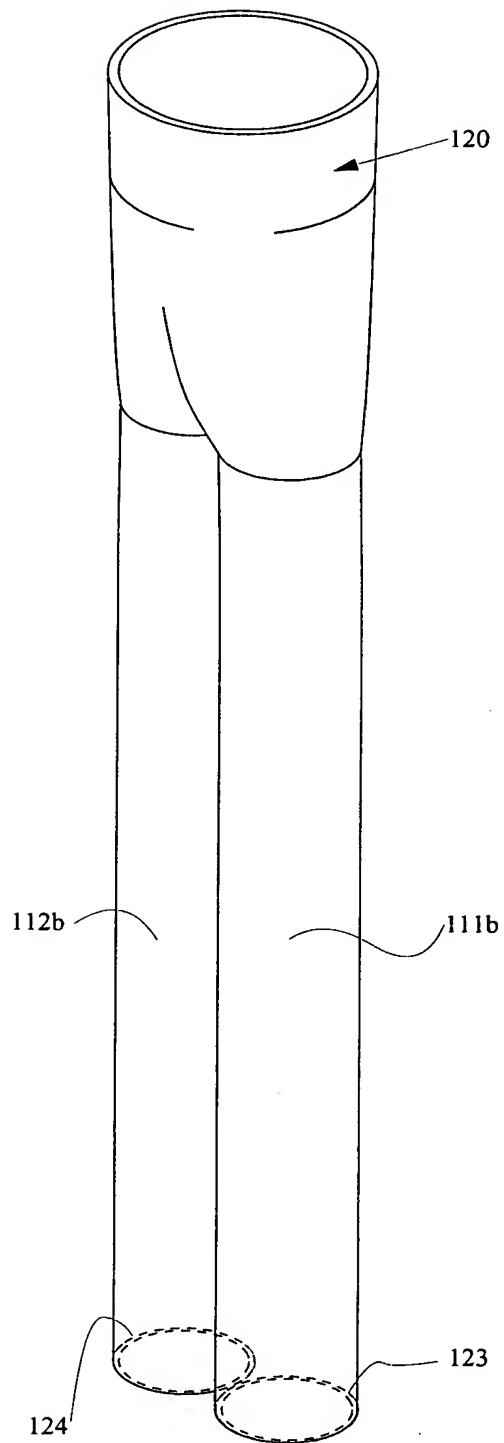


Fig 8



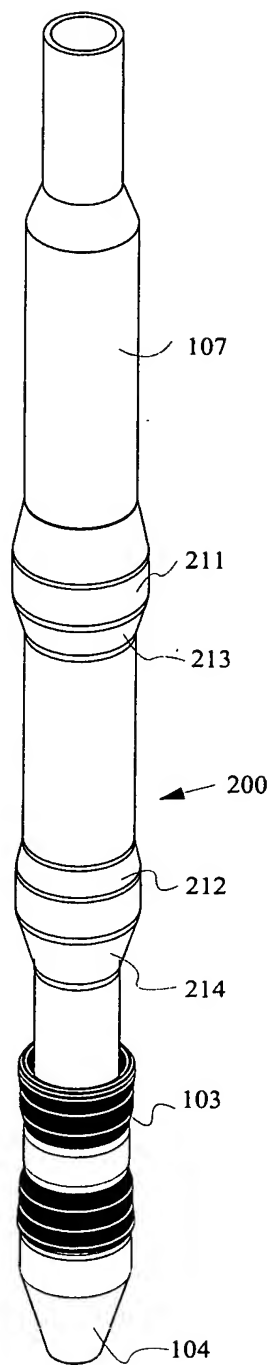


Fig 9

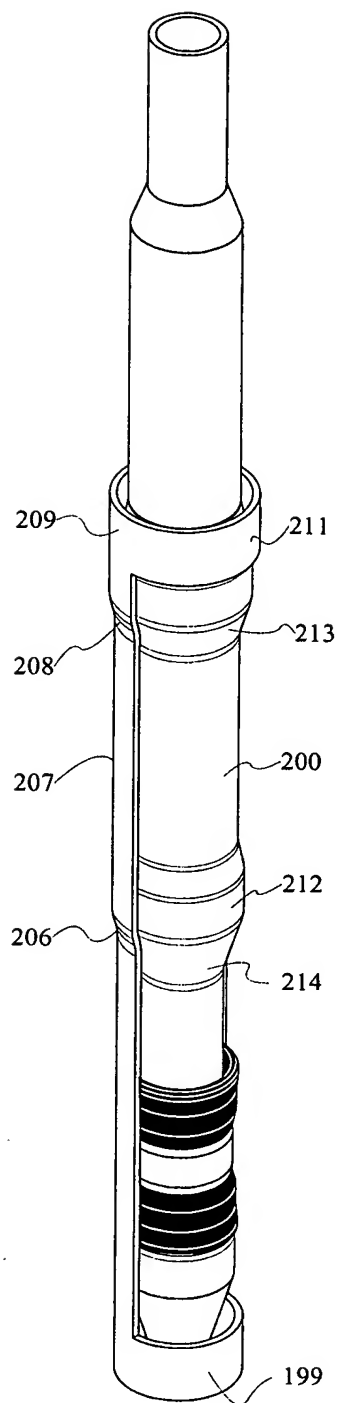


Fig 10

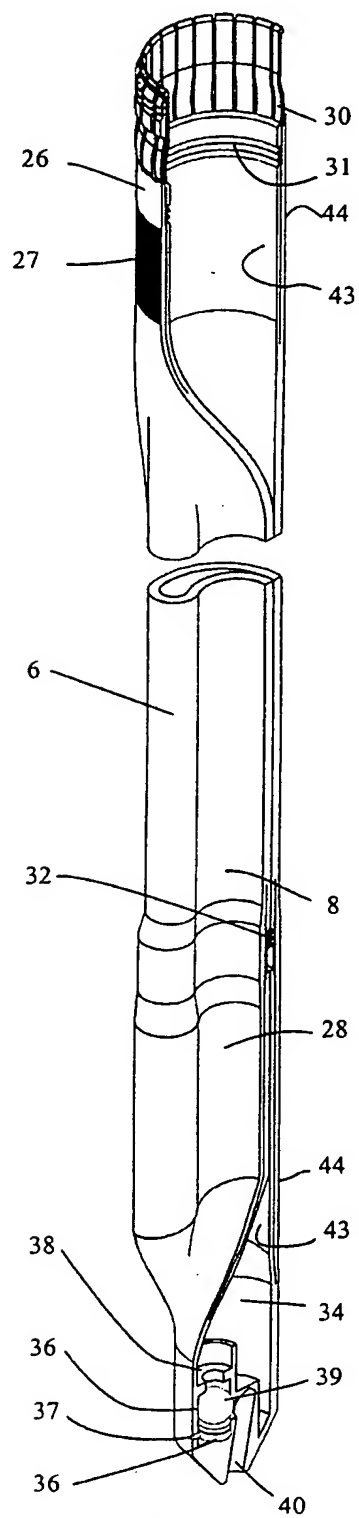


Fig 11

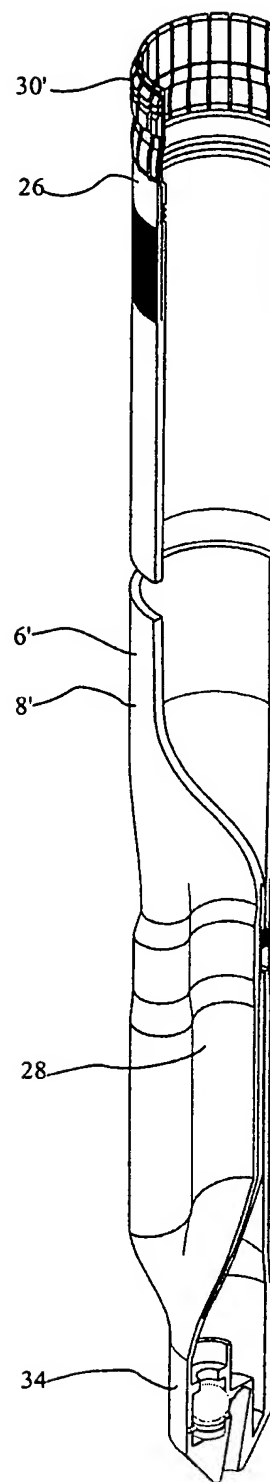


Fig 12

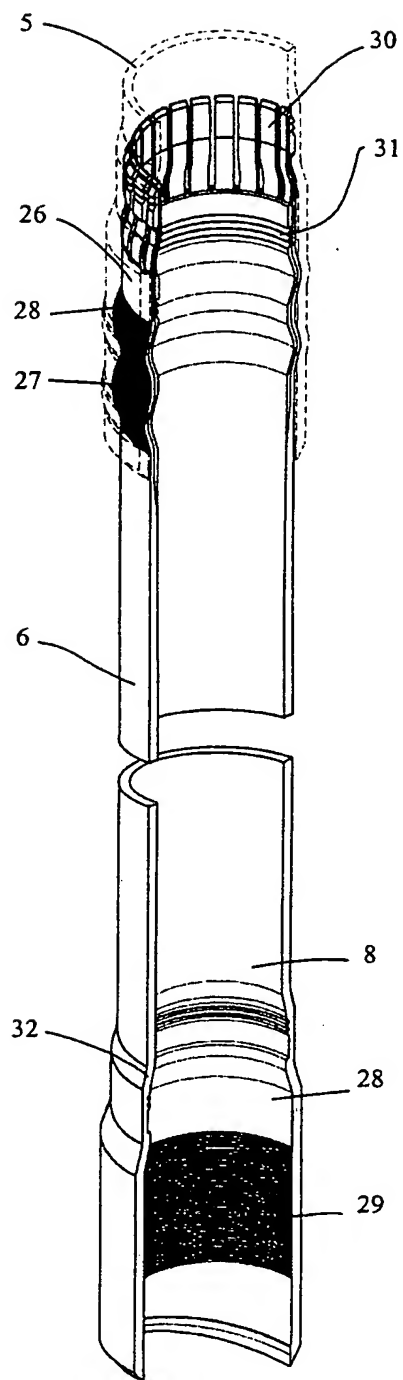


Fig 13